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(54) Hydraulic circuit for adjusting an operating cylinder of excavating equipment

(57) A hydraulic circuit for adjusting an operating cylinder 1 of excavating equipment, in which, to save energy, the working fluid which is discharged under pressure from the cylinder space (2) on one side of the piston when a component of the equipment is lowered under gravity is conveyed to the cylinder space (3) on the other side of the piston.

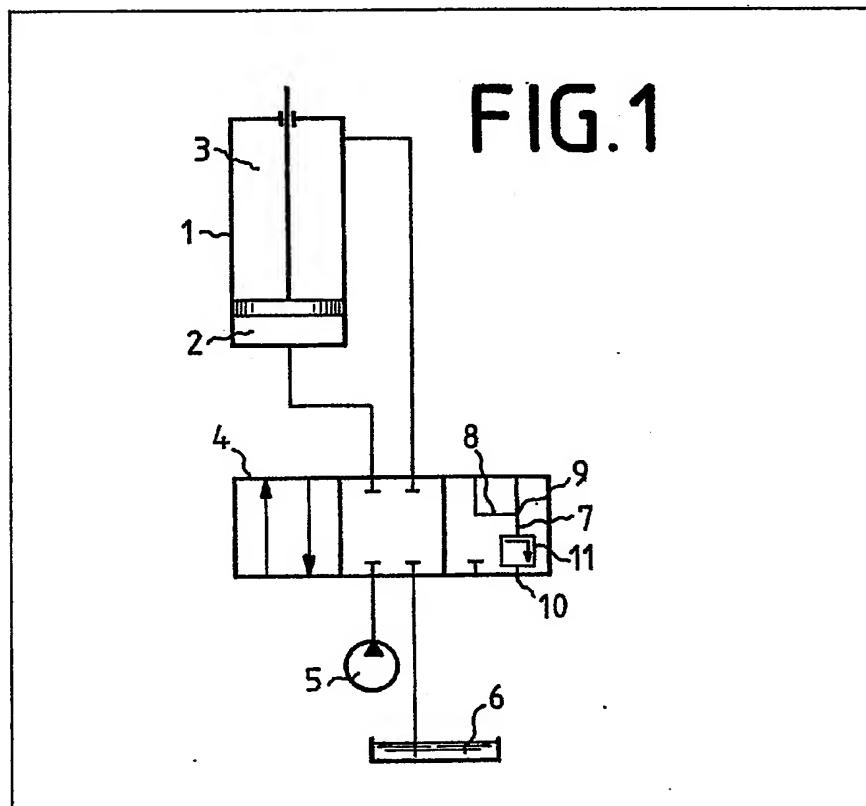


FIG.2

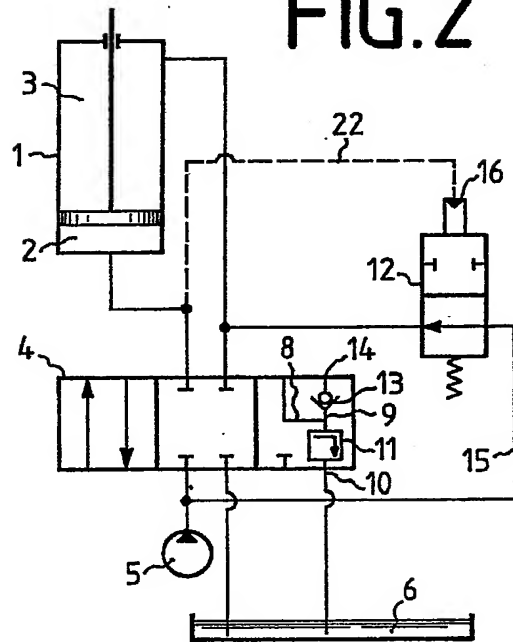


FIG. 3

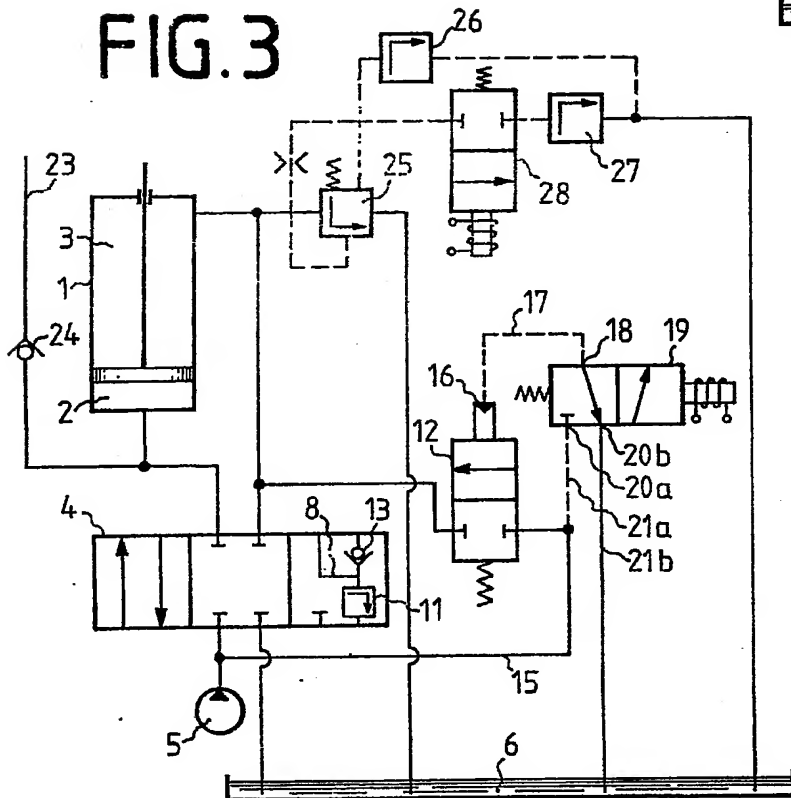


FIG. 4

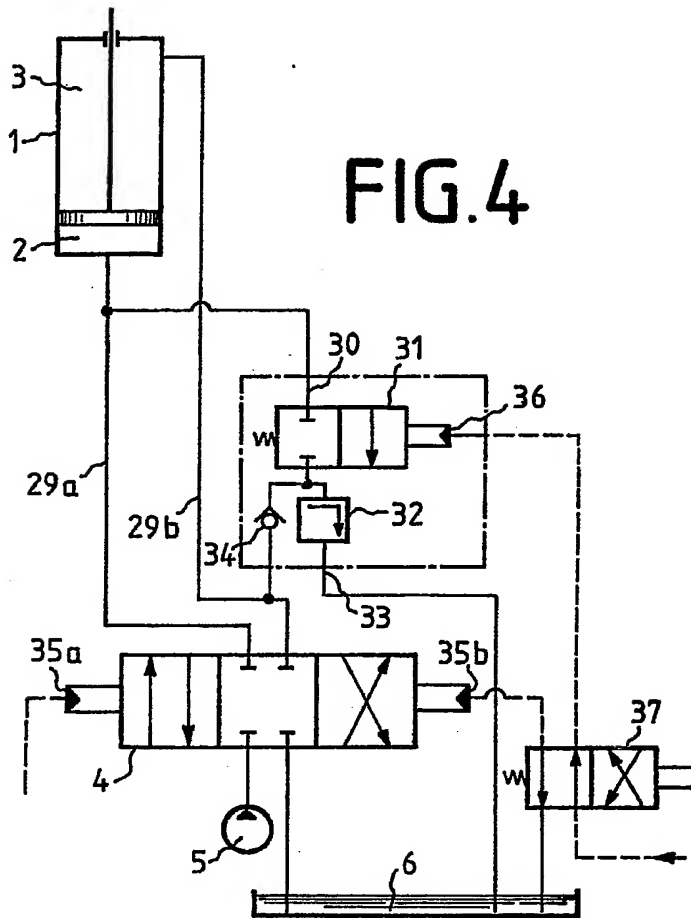
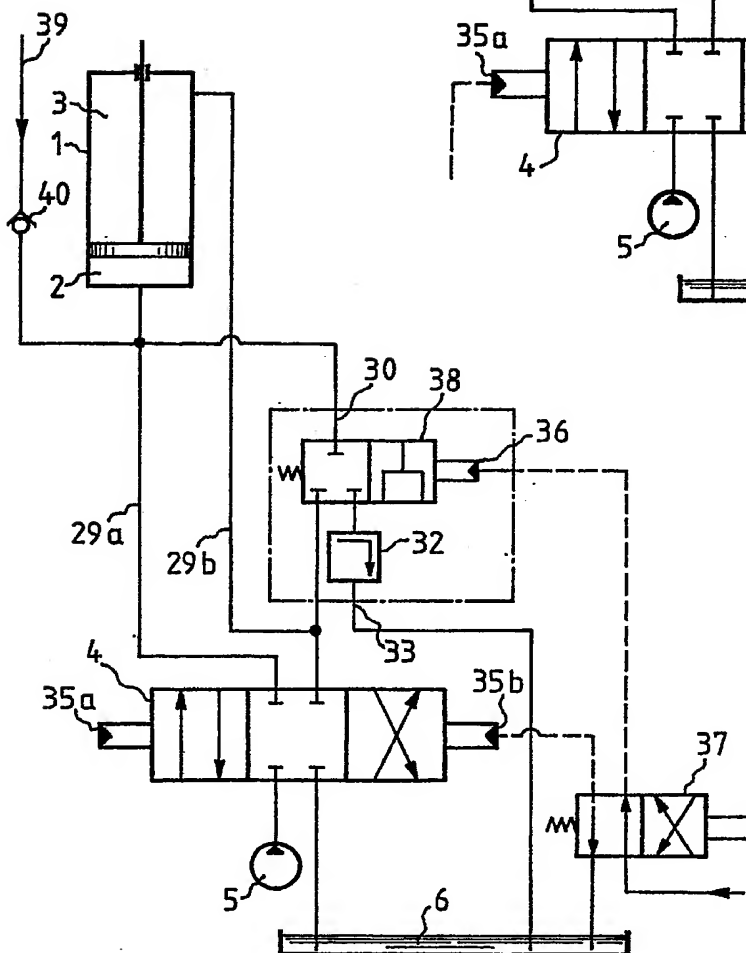


FIG. 5



SPECIFICATION

Hydraulic circuit for adjusting an operating cylinder of excavating equipment

5 The invention relates to a hydraulic circuit for adjusting an operating cylinder of excavating equipment, for example the boom cylinder or the arm cylinder of an hydraulic excavator.

10 Hitherto, the lowering of the boom and the arm of an excavator has been carried out by conveying fluid under pressure into the operating spaces of the appropriate cylinders. This method does not take into account the potential energy, both in the boom and in the arm, that could be used at least to assist this operation.

An object of the invention is to enable external forces acting on the boom and the arm of excavating equipment to be exploited during lowering of the boom and/or arm for transporting the working fluid into the appropriate operating cylinders.

The present invention provides a hydraulic circuit for adjusting an operating cylinder of excavating equipment, the circuit including a pump unit and a reservoir connectible to the cylinder to adjust the latter, and valve means operable to interconnect the cylinder spaces on each side of the piston when a component of the equipment is lowered under gravity, whereby fluid discharged from one cylinder space is conveyed to the other cylinder space.

30 The invention further provides a hydraulic circuit for adjusting an operating cylinder of excavating equipment, whose cylinder spaces on each side of the piston can be connected *via* control valve means to a pump unit and a reservoir to adjust the cylinder, the valve means also having a switching position in which a component of the equipment can be lowered under gravity, in which position the valve means blocks the supply line from the pump unit and provides an operational connection between one of the cylinder spaces and a line extending between the other cylinder space and the reservoir, such that fluid discharged from one cylinder space is conveyed to the other cylinder space.

45 In yet another form, the invention provides a hydraulic circuit for adjusting an operating cylinder of excavating equipment, whose cylinder spaces on each side of the piston can be connected *via* control valve means to a pump unit and a reservoir to adjust the cylinder, the valve means having three switching positions which represent respectively the following line associations:

1. a) a passage from the pump unit to one cylinder space and
 - 55 b) a return from the other cylinder space to the reservoir,
 2. a) passage from the pump unit blocked, and
 - b) return to the reservoir blocked,
 3. a) a passage from the pump unit to the said other cylinder space, and
 - 60 b) a return from the said one cylinder space to the reservoir,
- the circuit also including a lowering valve connected between the cylinder spaces and operable, when a component of the equipment is being lowered under

gravity, to provide an operational connection between the said one cylinder space and a line extending between the other cylinder space and the reservoir, such that fluid discharged from the said one cylinder space is conveyed to the other cylinder space, and in which a biased valve is connected in the said line between the operational connection and the reservoir.

By way of example, embodiments of the invention will now be described with reference to the accompanying drawings, in which:

70 Figures 1 to 3 show different designs of a first form of hydraulic circuit and

75 Figures 4 and 5 show different designs of a second form of hydraulic circuit.

80 In the individual Figures of the drawings, corresponding parts have the same reference numerals.

Figure 1 is a basic circuit for the operating cylinder 1 of a component of the excavating equipment of an hydraulic excavator. The cylinder space 2 on the piston side and the cylinder space 3 on the rod side of the cylinder 1 can be connected *via* operating lines and a control valve 4 to a pump unit 5 and a reservoir 6. The illustrated control valve 4 can assume any one of three switching positions, two of which represent the following line associations:

1. a) a supply line from the pump unit 5 to the cylinder space 2 on the piston side,
- b) a return from the cylinder space 3 on the rod side to the reservoir 6,
- 95 2. a) supply line from pump unit 5 blocked,
- b) return to reservoir 6 blocked.

The above-mentioned line associations can, however, be supplemented by others corresponding to the third switching position of the control valve 4, when the supply line from the pump unit 5 is blocked and a line 7 between the cylinder space 3 and the reservoir 6 is operational. In this case, there is provided a further operational connection 8 from the cylinder space 2 to the line 7.

105 In the first (left-hand) position of the control valve 4, the cylinder 1 can be extended under the action of the working fluid from the pump unit 5 on the piston surface in cylinder space 2 while fluid displaced from cylinder space 3 passes unhindered to the reservoir 6. In the third (right-hand) position of the control valve 4 the cylinder can be retracted under the weight of the excavating equipment acting on the piston rod to displace fluid from the cylinder space 2 into the cylinder space 3 and to the reservoir 6. Since experience has shown that a relatively high line resistance is to be expected in the connection to the cylinder space 3, a biased valve 11 is provided in the connection to the reservoir 6 to ensure that connection to the cylinder space 3 has priority.

120 The hydraulic circuit shown in Figure 1 cannot be used when there are no external forces acting on the piston rod to retract the cylinder, that is, when the dead centre position has been exceeded.

Figure 2 shows a hydraulic circuit which has automatic change-over to normal operation (i.e. retraction of cylinder 1 under the action of the working fluid from the pump unit 5) when the dead centre position has been reached. The circuit is similar to that shown in Fig. 1 with the addition of an external change-over valve 12 and a non-return valve 13 inserted, in the

valve 4, between the junction 9 of the line 7 and operational connection 8 and the supply 14 of working fluid the cylinder space 3. The non-return valve 13 has a blocking action with respect to fluid flow from the supply 14 to the junction 9.

Parallel to the control valve 4, that is to say by-passing the control valve, is a by-pass line 15 by which the pump unit 5 is connected to a change-over valve 12. The change-over valve 12 has a control input 16 which can be connected to the cylinder space 2 either directly via a control line 22 when the valve 4 is in the position shown or, when the valve 4 is in the right-hand position, indirectly through the connection of the control line 22 to the line interconnecting the cylinder spaces 2 and 3. In this way, the cylinder pressure is used as a switching signal for the valve 12. When the dead centre position is reached during retraction of the cylinder 1, that is to say when there are no external forces, for example gravity, acting on the piston rod, the cylinder pressure moves towards zero and allows the change-over valve 12 to move, under the action of the biasing spring, into the position illustrated. The change-over valve 12 must be able to render possible at least the following two line associations.

1. Passage open from pump unit 5 to the cylinder space 3 (as illustrated).
2. Passage blocked.

Figure 3 shows an alternative arrangement for control of the change-over valve 12. In this case, the control input 16 of the valve is connected via a control line 17 to an operating connection 18 of a solenoid valve 19. The other operating connections 20a and 20b of the solenoid valve 19 are provided with respective lines 21a and 21b which lead to the pump unit 5 and the reservoir 6 whereby, in one position of the solenoid valve 19, the control input 16 of the change-over valve 12 is connected to the pump 5 and, in the other position, is connected to the reservoir 6.

Operation of the cylinder 1, using the hydraulic circuits shown in Figures 2 and 3, is as follows:
In order to extend the cylinder, the control valve 4 is brought into a switching position having the following line associations.

- a) Connection of the pump unit 5 to the cylinder space 2 and
- b) connection of the cylinder space 3 to the reservoir 6.

The working fluid, conveyed by the pump unit 5, then acts on the piston surface in the cylinder space 2 and the volume of fluid displaced from the cylinder space 3 passes unhindered into the reservoir 6.

In order to retract the cylinder, the control valve 4 is changed over to the right-hand switching position shown in the Figures. As a result of the external forces acting on the piston rod, a reaction pressure is formed in the cylinder space 2 and, in the Fig. 2 circuit, acts via the control line 22 on the change-over valve 12 so that the external connection 15 from the pump unit 5 to the cylinder space 2 is blocked. In the Fig. 3 arrangement, the same result is achieved through the action of the solenoid valve 19. At the same time, the connection from the pump unit 5 to the cylinder space 2 via the control valve 4 is interrupted and the cylinder space 2 is connected instead to the connection 8 leading,

within the control valve, to the biased valve 11 and non-return valve 13. Only some of the volume of fluid displaced from the cylinder space 2 passes via the biased valve 11 to the reservoir 6 since the pressure at the biased valve 11 is adjusted to be higher than the line resistance via the non-return valve to the cylinder space 3 so that the latter is given priority.

When the dead centre of the movement of the excavator equipment is reached there is no longer an external force on the piston rod and, consequently, also no reaction pressure from the cylinder space 2. In the Fig. 2 arrangement, this results in the change-over valve 12 being switched into the position illustrated in which the passage 15 from the pump unit 5 is connected to the cylinder space 3 so that the pump unit causes the retraction of the cylinder to continue. The connection from cylinder space 3 to the reservoir 6 is blocked by the non-return valve 13 but the working fluid displaced from the cylinder space 2 passes to the reservoir 6 via the biased valve 11.

In the Fig. 3 arrangement, an electrical command pulse is used for actuating the change-over valve 12 via the solenoid valve 19 to continue the retraction of the cylinder 1.

Also shown in Figure 3 is a top-up line 23 which can feed into the cylinder space 2 via top-up line non-return valve 24. The top-up supply is used during operation of the excavator equipment in a so-called "floating position" as will be described below.

Finally, Figure 3 shows a pilot-operated pressure relief valve 25, which is conventionally provided for safety reasons in the cylinders of excavator equipment, together with an upper pilot valve 26, a lower pilot valve 27 and a further solenoid valve 28 the function of which will also be described below. The terms "upper" and "lower" with respect to the pilot valves refer to the pressure values or pressure ranges in which they control the pressure relief valve 25. Preferably the upper pilot valve 26 is set at a pressure approximately 10 times greater than the lower pilot valve 27. Operation of excavator equipment in the "floating position" is important in practice to the users of excavators and, accordingly, a desired feature of excavator equipment. It implies the possibility of the position of the excavator equipment being changed, either upwards or downwards, by external forces acting on it. In particular, it is required that, under the force of gravity, the equipment (especially the bucket fastened to the arm) should be able to approach the ground or rest on it but that the bucket should also be lifted against the force of gravity when acted upon by external forces resulting from the unevenness of the ground.

With the hydraulic circuit shown in Figure 3, the above-mentioned floating position can be produced as follows. Firstly, for the cylinder to be capable of being retracted in the "floating position" for example as a result of the action of gravity, the connection from the pump unit 5 to the cylinder space 3 is blocked externally and internally. This is achieved when the control valve 4 has been brought into the right-hand switching position and the change-over valve 12 is in the position shown. An external load which pushes in the direction of retraction of the cylinder then causes working fluid to be fed from the cylinder space 2 via

the non-return valve 13 into the cylinder space 3. Some of the volume of fluid from the cylinder space 2 is removed *via* the biased valve 11 to the reservoir, this being necessary because the total volume of the cylinder space 2 is greater than that of the cylinder space 3.

The second possibility, that is, where an external force acts against the direction of gravity, (for example, as a result of the unevenness of the ground) can also be accommodated as follows. The command signal that brings the control valve 4 into the position already described is accompanied by a command signal for the solenoid valve 28. The result is that the pilot-operated pressure relief valve 25 is adjusted to a low pressure range *via* the lower pilot valve 27 and working fluid can then escape from the cylinder space 3 *via* the adjusted pressure relief valve 25 to the reservoir 6. A corresponding volume of working fluid for the cylinder space 2 flows in *via* the top-up line 23 and the top-up line non-return valve 24. Because the working fluid is able to flow freely between the cylinder spaces, the position of the equipment is not locked but freely movable.

Finally, with regard to the hydraulic circuit shown in Figure 3, the retraction of the cylinder under the action of the pump unit 5 will also be explained for completeness since it involves the upper pilot valve 26. The control valve 4 is again in the right-hand switching position already described. In addition, there is emitted by an external command source, to the solenoid valve 19, a special signal which is at the same time an erasing signal for the other solenoid valve 28. The pressure relief valve 25 is thereby adjusted to the high pressure range *via* the upper pilot valve 26 and, as a result of the switching of the solenoid valve 19 and therefore the change-over valve 12, the pump unit 5 feeds working fluid *via* the by-pass line 15 and the change-over valve 12 into the cylinder space 3. The working fluid from the cylinder space 2 on the piston side passes *via* the biased valve 11 to the reservoir 6.

Figure 4 shows another form of hydraulic circuit in accordance with the invention. As in the previously-described circuits, a cylinder 1 on a hydraulic excavator has cylinder spaces 2, 3 on the piston side and rod side, which can be connected *via* working fluid lines and a control valve 4 to a pump unit 5 and a reservoir 6. In this circuit the three switching positions of the control valve 4 represent the following line associations.

1. a) passage from the pump unit 5 *via* a line 29a to the cylinder space 2 on the piston side,
- b) return from the cylinder space 3 on the rod side *via* a line 29b to the reservoir 6,
2. a) passage from the pump unit 5 blocked,
- b) return to reservoir 6 blocked,
3. a) passage from the pump unit 5 *via* the line 29b to the cylinder space 3 on the rod side,
- b) return from the cylinder space 2 on the piston side *via* the line 29a to the reservoir 6.

Between the lines 29a, 29b from the cylinder spaces 2, 3 to the control valve 4, a lowering valve 31 is arranged in a line 30. Parallel to the downstream section of the line 30 there is provided, *via* a biased valve 32, a diverting line 33 to the reservoir 6 while the

downstream section of the line 30 itself includes a non-return valve 34 which allows passage in the direction of the line 29b.

In an alternative arrangement, shown in Figure 5, the lowering valve 31 of Figure 4 is replaced by a modified lowering valve 38 in which the parallel connection shown in Figure 4 downstream of the valve is already effected by the valve 38 itself so that it is then no longer necessary to provide the non-return valve 34.

In both Figures 4 and 5, the control valve 4 is shown with control connections 35a and 35b and the lowering valve 31 has a control input 36. The latter and the control connection 35b are actuated by the operating outputs of a change-over slide valve 37.

Finally, Figure 5 shows an additional top-up line 39 and non-return valve 40 connected to the cylinder space 2.

The mode of operation of the hydraulic circuits according to Figures 4 and 5 is as follows:

The extension of the cylinder 1 requires a line association through the control valve 4 such that the pump unit 5 is connected to the cylinder space 2, and the cylinder space 3 is connected to the reservoir 6. This corresponds to the left-hand switching position of the control valve 4, as shown immediately next to the control connection 35a.

When the cylinder is retracted under the action of an external force, for example the load of the excavator equipment, the change-over slide valve 37 is in the position shown in the drawings and a control signal passes to the lowering valve control input 36 which brings the lowering valve into the opposite position to that shown. Flow is then possible from the cylinder space 2 *via* the lowering valve 31 (and, in Figure 4, the non-return valve 34) to the line 29b and thence to the cylinder space 3. At the same time, some of the working fluid flows from the cylinder space 2 *via* the biased valve 32 and the diverting line 33 to the reservoir 6.

If the excavator equipment comes to rest as a result of coming into contact with the ground, the cylinder 1 remains in the retracted position it has reached. Further retraction of the cylinder, now under the action of the pump unit 5, requires the emission of a switching pulse to the input of the change-over slide valve 37 so that this valve moves into the other switching position. The active signal for the lowering valve control input 36 is, therefore, interrupted and a signal is passed to the control connection 35b of the control valve 4 so that it assumes the right-hand switching position shown immediately next to the control connection 35b. The pump unit 5 is then connected *via* the control valve 4 and the line 29b to the cylinder space 3 and, at the same time, the working fluid escapes from the cylinder space 2 *via* the control valve 4 into the reservoir 6.

An especially simple means of achieving operation of the excavator equipment in the floating position is permitted by the modified hydraulic circuit according to Figure 5.

The extension and retraction of the cylinder are, as already indicated, carried out by the switching operations just explained.

In order for the excavator equipment to reach a

floating position, the change-over slide valve 37 must be in the position shown and a command signal is passed to the lowering valve control input 36 so that the lowering valve 38 moves into the right-hand

5 switching position. As already described, the lowering valve 38 then connects the cylinder space 2 to the cylinder space 3 *via* the line 29*b* and the cylinder 1 is retracted until the equipment contacts the ground and then remains in this position. As a result of other
10 external forces, resulting, for example, from the contact with the ground and acting in the opposite direction, an extension of the cylinder takes place since, due to the connection described above, a free flow of the working fluid between the cylinder spaces
15 is possible. A differential quantity of the working fluid which may possibly be required is supplied *via* the top-up line 39.

This floating position is cancelled and the cylinder 1 is locked by removing the command signal previously-
20 ly-applied at the lowering valve control input 36. A new signal is emitted to the input of the change-over slide valve 37 which switches into the opposite position to that shown and passes a signal to the control connection 35*b* of the working fluid control
25 member 4. The previously-described switching position of the control valve 4 is thus again produced, in which the pump unit 5 feeds *via* the line 29*b* into the cylinder space 3 and the cylinder 1 is retracted.

It is readily possible to replace the hydraulic signal
30 supply to the control connections 35*a* and 35*b* and to the control input 36 by mechanical, pneumatic or electrical signal lines.

The cylinder may be the boom cylinder of an excavator or it may be the arm cylinder of the
35 excavator. Moreover, the cylinder 1 need not be a single cylinder but could be formed by the parallel connection of a plurality of cylinders.

CLAIMS

1. A hydraulic circuit for adjusting an operating
40 cylinder of excavating equipment, the circuit including a pump unit and a reservoir connectible to the cylinder to adjust the latter, and valve means operable to interconnect the cylinder spaces on each side of the piston when a component of the equipment is
45 lowered under gravity, whereby fluid discharged from one cylinder space is conveyed to the other cylinder space.

2. A hydraulic circuit according to claim 1, including means operable, when the pressure of the fluid
50 discharged from the cylinder space falls to a predetermined value, to connect the cylinder to the pump unit to be adjusted thereby.

3. A hydraulic circuit according to claim 2, in which the predetermined value is approximately equal to
55 zero.

4. A hydraulic circuit according to any one of claims 1 to 3, in which the valve means is operable to interconnect the cylinder spaces by providing an operational connection between one of the cylinder
60 spaces and a line extending between the other cylinder space and the reservoir.

5. A hydraulic circuit for adjusting an operating cylinder of excavating equipment, whose cylinder spaces on each side of the piston can be connected *via*
65 control valve means to a pump unit and a reservoir to

adjust the cylinder, the valve means also having a switching position in which a component of the equipment can be lowered under gravity, in which position the valve means blocks the supply line from the pump unit and provides an operational connection between one of the cylinder spaces and a line extending between the other cylinder space and the reservoir, such that fluid discharged from one cylinder space is conveyed to the other cylinder space.

70 6. A hydraulic circuit according to claim 5, including a biased valve connected in the said line between the operational connection and the reservoir.

7. A hydraulic circuit according to claim 6, including a non-return valve connected in the said line
75 between the cylinder space and the operational connection to block fluid flow towards the operational connection.

8. A hydraulic circuit according to any one of claims 5 to 7, including a by-pass line connected
85 parallel to the valve means and including a change-over valve operable to connect the pump unit to the said other cylinder space *via* the by-pass line.

9. A hydraulic circuit according to claim 8, in which the change-over valve has a control input connected
90 to the said one cylinder space.

10. A hydraulic circuit according to claim 8, in which the change-over valve has a control input connected to an operating connection of a solenoid valve.

11. A hydraulic circuit according to claim 10, in which the solenoid valve has other operating connections connected, respectively, to the pump unit and to the reservoir.

12. A hydraulic circuit according to claim 10 or
100 claim 11, in which a pressure relief valve is connected to the said other cylinder space.

13. A hydraulic circuit according to claim 12, in which the pressure relief valve has an operating characteristic which can be adjusted to lie within one or other of two predetermined pressure ranges.

14. A hydraulic circuit according to claim 13, in which the pressure ranges differ by a factor of approximately 10.

15. A hydraulic circuit according to any one of claims 10 to 14, in which a top-up line is connected, *via*
110 a non-return valve, to the said one cylinder space.

16. A hydraulic circuit for adjusting an operating cylinder of excavating equipment whose cylinder spaces on each side of the piston can be connected *via*
115 control valve means to a pump unit and a reservoir to adjust the cylinder, the valve means having three switching positions which represent respectively the following line associations:

1. a) a passage from the pump unit to one cylinder
120 space and
b) a return from the other cylinder space to the reservoir,

2. a) passage from the pump unit blocked, and
b) return to the reservoir blocked,

125 3. a) a passage from the pump unit to the said other cylinder space, and

b) a return from the said one cylinder space to the reservoir,

130 the circuit also including a lowering valve connected between the cylinder spaces and operable, when a

component of the equipment is being lowered under gravity, to provide an operational connection between the said one cylinder space and a line extending between the other cylinder space and the reservoir, such that fluid discharged from the said one cylinder space is conveyed to the other cylinder space, and in which a biased valve is connected in the said line between the operational connection and the reservoir.

17. A hydraulic circuit according to claim 16, including a non-return valve connected in the said line between the said other cylinder space and the operational connection to block fluid flow towards the operational connection.

18. A hydraulic circuit according to claim 15 or claim 16, in which the control valve means and the lowering valve have control connections connected to the outputs of a change-over valve.

19. A hydraulic circuit according to any one of the preceding claims in which the cylinder is formed by the parallel connection of several individual cylinders.

20. A hydraulic circuit according to any one of the preceding claims, in which the cylinder is a boom cylinder of an hydraulic excavator.

21. A hydraulic circuit according to any one of claims 1 to 19, in which the cylinder is an arm cylinder of an hydraulic excavator.

22. A hydraulic circuit for adjusting an operating cylinder of excavating equipment, substantially as described herein with reference to and as illustrated by Fig. 1 or Fig. 2 or Fig. 3 or Fig. 4 or Fig. 5 of the accompanying drawings.